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(54) **COMBINATION OF ELECTROMAGNETIC AND ELECTROPOTENTIAL LOCALIZATION**

KOMBINATION AUS ELEKTROMAGNETISCHER UND ELEKTROPOTENTIAL-LOKALISIERUNG

ASSOCIATION DE LOCALISATION ELECTROMAGNETIQUE ET PAR POTENTIEL ELECTRIQUE

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Description

FIELD

[0001] The present disclosure relates generally to a system for localizing a tracked instrument, and particularly to a localization system using two or more modalities for localizing the instrument within a volume.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] A navigation system can be used to track and navigate an instrument within a volume. For example, a navigation system can be used to track an instrument during a procedure, such as a surgical procedure. Various systems can be used to track instruments including electromagnetic systems, optical systems, acoustic systems, and other appropriate systems.

[0004] Tracking an instrument can allow for determination of a position of the instrument relative to the patient without directly viewing the instrument within the patient. Various methods can be used to achieve this result, such as directly tracking a particular portion of the instrument exterior to the patient or tracking a distal point of the instrument within the patient.

[0005] Differing navigation systems can be used to track different instruments within a patient. For example, a long substantially rigid instrument can be tracked with an optical navigation system that can track a proximal and/or end of the instrument that is external to the patient. Based on determinations, a position of a distal tip or an end of the instrument within the patient can be made. Additionally, navigation systems can use fields, such as electromagnetic fields, to track and navigate a distal portion of an instrument that is within a patient.

[0006] US 6 574 498 discloses a system for tracking a catheter within a patient using a combination of an electromagnetic sensor and an electropotential sensor.

SUMMARY

[0007] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0008] A navigation system or combination of navigation systems can be used to provide two or more types of navigation or modalities of navigation to navigate a single instrument. The single instrument can be positioned within the patient and tracked. For example, both an Electromagnetic (EM) and Electropotential (EP) tracking systems can be used to navigate an instrument within a patient.

[0009] A navigation system can generally include a localizer and a tracking sensor. One skilled in the art will understand that the localizer can either transmit or receive a signal and the tracking sensor can also transmit or receive a signal to allow for a determination of a location of the tracking sensor associated with the surgical instrument. A surgical instrument can have associated therewith two or more tracking sensors that can be used in two or more modalities of navigation. For example, a surgical instrument may include an electrode that can be used with an EP tracking system and can also be associated or moved relative to a tracking sensor that includes an EM coil to be used with an EM tracking system.

[0010] An instrument can include one or more tracking sensors to be used with two or more navigation systems during a single procedure. In addition, a method can be used to register the two navigation systems during a single procedure. The registration of the two navigation systems can allow all or a selected number of points within one navigational domain to be coordinated or correlated to all or selected points in a second navigational domain. For example, a surgical instrument can include a single tracking sensor that can be tracked within two navigation modalities. Also, a surgical instrument with a single tracking sensor can be moved relative to a second tracking sensor, where each of the tracking sensors are tracked in different navigation modalities. According to various embodiments, when a first tracking sensor is positioned at a known location relative to a second tracking sensor, a navigation volume or domain of the first navigation system can be registered to a navigation volume or domain of a second navigation system. In this way, a first and second navigation system can be registered for navigating a tracking sensor or a surgical instrument within the two navigation modalities.

[0011] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0012] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0013] Fig. 1 is an environmental view of a navigation system;

[0014] Fig. 2A is a detailed cross-section view of an instrument, according to various embodiments;

[0015] Fig. 2B is a detailed cross-section and environmental view of an instrument, according to various embodiments;

[0016] Fig. 3 is a detailed cross-section view of an instrument, according to various embodiments;

[0017] Fig. 4 is an environmental view of a navigation system, according to various embodiments;

[0018] Fig. 5 is a flow chart of a method of registering two navigation systems;

[0019] Fig. 6 is a view of image data and icons dis-

played relative to the image data, according to various embodiments;

[0020] Fig. 7A-7C are detailed flowcharts of registration of two tracking systems; and

[0021] Fig. 8 is a detailed view of navigating a registered instrument.

[0022] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0023] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0024] A surgical navigation system 20 is illustrated in Fig. 1. A first tracking system can include an electropotential (EP) tracking system 22. A second tracking system can include an electromagnetic (EM) tracking system 24. Appropriate tracking systems can include those disclosed in U.S. Patent App. No. 12/117,537, filed on May 8, 2008 and U.S. Patent Publication No. 2004/0097805, published on May 20, 2004, both incorporated herein by reference. The first and second tracking systems 22, 24 can be used to track a surgical instrument 26. The surgical instrument 26 can be any appropriate instrument, including a lead used as a part of an implantable medical device (IMD) for heart rhythm treatment, neurological treatment, or other appropriate purposes.

[0025] The surgical navigation system 20 can also include other components, such as an imaging system 30. The imaging system 30 can be any appropriate imaging system and is exemplary illustrated as a fluoroscopic C-arm system 32. Other imaging systems can include computed tomography (CT) imaging systems, magnetic resonance imaging (MRI) systems, and positron emission tomography (PET) imaging systems. The imaging systems 30 can be used by a surgeon 34 to image a patient 36 prior to (preoperatively), during (intraoperatively), or after (postoperatively) a procedure. Imaging the patient 36 can create image data that can be viewed on a display device 38 or a display device 40. The display device 38, 40 can be provided alone, such as on a stand 42 or with a processing system as a part of a workstation or processing system 44. The image data can be transferred from the imaging system 30 through a data transmission system 46, such as a wired or wireless transmission system, to the display devices 38, 40.

[0026] The navigation system 20, also including the tracking systems 22, 24 can be incorporated or connected to the processor system 44. The processor system 44 can include human input devices such as a keyboard 48, a joystick or mouse 50, a foot pedal 52 or any other appropriate human input device. Each of the human input devices 48-52 can be connected with the processor system 44 or other systems, such as the imaging system 30, for control or actuation thereof.

[0027] The EP tracking system 22 can include components to generate a current in the patient 36. The EP tracking system can include or be based on the Localisa™ intracardiac tracking system sold by Medtronic, Inc. have a place of business in Minneapolis, Minn. The EP tracking system 22 can also include portions disclosed in U.S. Patent Numbers 5,697,377 or 5,983,126 to Wittkampf

[0028] Briefly, the EP tracking system 22 can include a pair of axis electrodes, which can also be referred to as a localizer, operable to generate a current within a volume, such as the patient 36. The axis electrodes can include three pairs of axis electrodes to generate three substantially orthogonal axes of current within the patient 26 (also see Fig. 4). The axis electrodes can include a first pair 60a, 60b, a second pair 62a, 62b, and a third pair 64a, 64b. The axis can be defined by an alternating current that is generated between any pair of the axis electrodes. For example, the first pair of axis electrodes 60a and 60b can be positioned on a left and right side of the patient 36 to define an X-axis when a current is generated between the two axis electrodes 60a and 60b.

[0029] The substantially orthogonal axis of current can be used to determine or calculate a location of a tracking device 70. The tracking device 70 can include a first or EP tracking device 70a and a second or EM tracking device 70b. The EP tracking system 22 can be used to track the EP tracking device 70a. The first tracking device 70a can sense a voltage in the patient 36 based upon the induced current between any pair of the axis electrodes 60a-64b. The voltage can be related to a position of the first tracking device 70a in the patient 36.

[0030] The pairs of axis electrodes 60a-64b can be driven with a generator in a controller 72 that is connected via wires or wirelessly with the axis electrodes 60a-64b. The generator can provide the power to generate the alternating current in the patient 36 between the respective the axis electrodes 60a-64b. The controller 72 can also include a connection for the instrument 26 to communicate a signal from the tracking device 70 to the controller. The connection with the instrument 26 can be wired or wireless, according to various embodiments. In addition, the controller 72 can include a processor portion or simply be a transmitter to transmit signals from the tracking device 70. Signals can be transmitted from the controller 72 to the processor system 44 with a transmission system 74. The transmission system 74 can be a wired or wireless transmission system.

[0031] The EM tracking system 24 can also be associated with the controller 72 or can be provided with a separate controller system. It will be understood that various separate circuitry portions may be provided in the controller 72 to generate or operate the EP tracking system 22 or the EM tracking system 24.

[0032] The EM tracking system 24 includes an EM localizer 76 that can be positioned relative to the patient 36. The EM tracking system can include the AxiEM™ electromagnetic tracking system sold by Medtronic Navigation, Inc. having a place of business in Colorado, USA. The localizer 76 can generate an electromagnetic field

that is sensed by the EM tracking device 70b. Alternatively, the EM tracking device 70b can generate a field that is sensed by the localizer 76.

[0033] A localizer can be used as a part of a tracking system to determine the location of the tracking device 70. For example, the localizer 76 can be interconnected with the controller 72 to transmit a signal to the processor system 44 regarding the position of the EM tracking device 70b. The axis electrodes 60a-64b can be a localizer that induces axes of current in the patient 36 to localize the EP tracking device 70a. Accordingly, the localizer can refer to a portion of the tracking system which can be exterior to the volume, such as the patient 36, that is used to determine a position of the tracking device 70.

[0034] According to various embodiments, the localizer devices, including the EM localizer 76 and the axis electrodes 60a-64b, can be used to define a navigation domain in a patient space of the patient 36. Patient space can be the physical space that is being operated on during the operative procedure. The patient space can also include the navigated space through which the surgical instrument 26 is being navigated. Image space can be defined by image data 80 that is displayed on the display devices 38, 40. Image data 80 can include any appropriate image data, such as image data of a heart 84 (Fig. 4) of the patient 36. the image data 80 displayed on the display devices 38, 40 can also include atlas data. Atlas data can include statistical or historical data. The atlas data can be registered or morphed to the patient image data or patient space. It will be understood that atlas data may be used in an imageless navigation system. For example, an imageless navigation system may not require the acquisition of image data of the patient 36.

[0035] The patient space can be registered to the image space of the image data 80 according to any appropriate technique, including those discussed herein. Generally, however, the patient space is registered to the image data 80 to allow for displaying or a super imposing an icon or representation of a tracked device, for example the surgical instrument 26, over the image data 80 on the display device 38, 40. Registration generally allows for a transformation of the image data to the patient space. Various registration techniques can include contour matching, fiducial or point matching, automatic registration, or any other appropriate registration. For example, various landmarks or fiducials can be identified in the image data 80 and the same fiducials or landmarks can be identified in the patient 36, such as within the heart 84. The image data 80 can then be transformed to the patient space of the patient 36 so that a proper location of a superimposed icon 26i can be shown relative to the image data 80 of the heart 84. Registration techniques can include those discussed in the U.S. Patent Applications incorporated above. In addition, as discussed herein, the EP tracking system 22 can be registered to the EM tracking system 24. The registration of the EP tracking system 22 to the EM tracking system 24 can allow navigation of the EP tacking device 70a with the image data 80.

[0036] Turning to Figs. 2A and 2B, the tracking device 70 can include the two tracking devices 70a and 70b. The first tracking device 70a can be a single electrode or a tip electrode 90 or ring electrode (not illustrated) of a lead assembly 92. The lead assembly 92 can be a lead for any appropriate device, such as a pacing or defibrillator system. The lead assembly 92 can be positioned or delivered within a sheath 94 according to generally known lead assemblies, such as the such as the Attain family of catheters sold by Medtronic Inc., having a place of business in Minneapolis, MN.

[0037] The lead assembly 92 can be positioned within the patient 36, such as relative to the heart 84, with a catheter assembly 100. The catheter assembly 100 can be any appropriate configuration. The catheter 100 can include a body molded to substantially define a cannula. The catheter assembly 100 can include the second tracking device 70b. The second tracking device 70b can include a first coil 102 and a second coil 104, or any appropriate number of coils, as part of the EM tracking device 70b. The coils can be coiled with any appropriate configuration, such as around substantially orthogonal axes to one another. The second tracking device 70b, however, can sense an electromagnetic field generated with the localizer 76 or generate an electromagnetic field that is sensed by the localizer 76.

[0038] The two tracking devices 70a, 70b can be used with respective tracking systems 22, 24. The first tracking device 70a can sense a voltage or determine bioimpedance (such as an impedance of a tissue of the patient 36) because of the induced current from the axis electrodes 60a-64b. The inducement of the current generates a voltage that can be sensed with the EP tracking device 70a. The voltage sensed by the EP tracking device 70a can be transmitted to the controller 72 with an appropriate communication line, such as a conductor 106. The conductor 106 can be conductively coupled to the EP tracking device 70a. It will be understood that although the EP tracking device 70a is illustrated as the tip electrode 90 of the lead assembly 92, that the EP tracking device 70a can also include an alternative EP tracking device 70a' formed as a part of the sheath 94. Regardless of the position of the EP tracking device 70a, its contact (e.g. by removal of a portion of insulation around the electrode) with a conductive medium or electrolyte of the patient 36 can increase and provide efficiency of detecting an appropriate voltage. The voltage sensed by the EP tracking device 70a can be used to determine the position of the EP tracking device 70a as discussed further herein and also described in the above incorporated U.S. Patent Applications and Patents.

[0039] The second tracking device 70b, according to various embodiments, can sense an electromagnetic field generated by the localizer 76. For example, a current can be induced in one or more of the coils 102, 104 that is dependent upon the position of the coils 102, 104 in a portion of the electromagnetic field. The generated cur-

rent can be sent as a signal along a transmission line 108 to the controller 72.

[0040] As discussed further herein, and illustrated in Fig. 2B, the lead assembly 92 can be moved relative to tissue of the heart 84 to position the distal tip electrode 90 into the heart 84. When positioning the distal tip electrode 90 into the heart 84, the sheath 94 and the tip 90, which can include the first tracking device 70a, can move relative to the catheter assembly 100. Moving the first tracking device 70a relative to the catheter assembly 100 moves the first tracking device 70a relative to the second tracking device 70b. As discussed herein, this can be used to determine the location of the first tracking device 70a relative to the second tracking device 70b for registration of the EP tracking system 22 and the EM tracking system 24. This determination can be used to track the first tracking device 70a relative to the patient 36 and with the registered image data 80.

[0041] In addition, the tracking devices 70a and 70b could be the same coil of wire or conductive material provided with different insulation characteristics. For example, the loops or turns of the tracking device 70a can be electrically separated from the loops or turns of wire for the second tracking device 70b. Both sets of loops can be of the same length of wire over top one another. The conductive media or loops of the first tracking device 70a can be external and exposed to the patient to sense or measure the voltage in the patient. The second portion of the loops can be isolated from the patient and insulated, but they can, along with the first portion, sense the field of the EM tracking system 24.

[0042] Turning to Fig. 3, an instrument 120, according to various embodiments, is illustrated. The instrument 120 can include a lead assembly 121 substantially similar to the lead assembly 92 discussed above, including a tip electrode 90 and a sheath 94. The instrument 120 can also include a catheter assembly 122. The lead assembly 121, including the distal tip 90 and the sheath 94 can be moved relative to the catheter assembly 122.

[0043] The catheter assembly 122 can include the tracking device 70' as a single unit or device including an EP tracking device 70a' and one or more windings of an EM tracking device 70b'. The EM tracking device 70b' can be positioned substantially over or around the EP tracking device 70a'. The EP tracking device 70a' can include an annular ring that is molded into or formed with the catheter assembly 122. The EP tracking device 70a' can be used with the EP tracking system 22 similar to the distal tip electrode 90 of the lead assembly 92. The EM tracking device 70b' can be used with the EM tracking system 24 similar to the windings 102, 104 of the EM tracking device 70b. Nevertheless, the EP tracking device 70a' and the EM tracking device 70b' can be positioned substantially atop one another. This allows for the tracked position of the EP tracking device 70a' and the tracked position of the EM tracking device 70b' to be substantially coincident throughout a tracked procedure. A signal from either of the EP tracking device 70a' or the EM tracking device 70b' can be transmitted along or with a communication system 124, which can include a wired or wireless transmission system.

[0044] Again, it will be understood, that the tracking device 70' can be tracked with the two tracking systems 22, 24. As discussed above, the electrode of the EP tracking device 70a' can sense a voltage within the patient 36. The EM tracking device 70b' can sense a magnetic field or electromagnetic field or transmit a magnetic field or electromagnetic field. Accordingly, the single tracking device 70' can be used with two or more tracking systems 22, 24 to determine a location of the tracking device 70' and the catheter and lead assembly 120. It will be further understood that the tip electrode 90 of the lead assembly 121 can also be used as the EP tracking device with the EP tracking system 22.

[0045] With reference to Fig. 4, a tracking device 70" can include an EP tracking device 70a" and an EM tracking device 70b". The EP tracking device 70a" can be positioned on a first instrument portion 26a and the EM tracking device 70b" can be positioned on a second instrument portion 26b. The two instrument portions 26a, 26b can be positioned within the patient 36. Alternately, one of the two instrument portions 26 can be positioned relative to the patient 36 in any appropriate manner. For example, the second instrument portion 26b including the EM tracking device 70b" can be positioned on an exterior surface of the patient 36 or be implanted as a fiducial or dynamic reference frame in the patient 36, such as fixed relative to the heart 84.

[0046] The two tracking devices 70a" and 70b" can be moved relative to one another during an operative procedure. For example, if both of the tracking devices 70a" and 70b" are positioned on two separate and moveable instruments 26a, 26b they can be moved to a known position relative to one another within the patient 36 during an operative procedure. Alternatively, if the second instrument 26b is positioned at a fixed location relative to the patient 36, the first instrument portion 26a can be moved to a known position relative to the second instrument portion 26b during an operative procedure. For example, fluoroscopic or ultrasound imaging, such as with the imaging system 30, can be used to confirm or determine the known position of the first surgical instrument 26a and the second instrument 26b. Accordingly, during a second procedure, a position of the EP tracking device 70a" and the EM tracking device 70b" can be determined.

[0047] A location of the EP tracking device 70a" can be determined with the EP tracking system 22. The EM tracking system 24 can be used to determine the location of the EM tracking device 70b". As discussed further herein, the determined location of the two tracking devices 70a", 70b" can be used to register the EP tracking system 22 and the EM tracking system 24. The tracked position of the two instruments 26a, 26b can be used for illustration of an icon representing one or both of the instruments 26a, 26b on the display devices 38, 40 relative to the image data 80.

[0048] Turning reference to Fig. 5, a flow chart or navigation method for registering or coordinating a dual tracking system 130 is illustrated. The navigation method 130 is illustrated briefly in Fig. 5 and further detailed in Figs. 7A-7C and 8. The method of using a two tracking system navigation system will be discussed in an exemplary embodiment herein. It will be understood, however, that a navigation system including two or more tracking systems can be used according to various embodiments, including those discussed above. The assembly 92, however, is discussed as an exemplary embodiment.

[0049] The navigation method 130, as discussed in detail herein, allows for registration of the EP tracking system 22 to the EM tracking system 24 and further to the image data 80. The EM tracking system 24 can be registered to the image data 80, as discussed herein, including registering the navigation domain of the EM tracking system 24 with the image space. The EP tracking system 22, including the navigation domain of the EP tracking system 22, can be registered to the EM tracking system 24, including the EM navigation domain, according to various embodiments, such as using the devices discussed above. The registration of the EP tracking system 22 to the EM tracking system 24 can allow the EP tracking system 22 to be registered to the image data 80.

[0050] The navigation method 130 can include starting in start block 132. The image data 80 can then be acquired in block 134. In addition, with reference to Fig. 6, the image data 80 can be displayed on the display device 40. As discussed above, an icon 92i can be superimposed on the image data 80 to represent a location of an appropriate instrument, such as the surgical instrument 26. The image data 80 can include three dimensional or two dimensional image data that is acquired for representation or illustration of a portion of the patient 36. It will be further understood that the image data 80 acquired in block 134 can be image data that is acquired preoperatively, intraoperatively, or at any appropriate time. It may also include a combination of preoperative and intraoperative image data. For example, preoperative image data can be merged or registered with intraoperative image data according to any appropriate technique. For example, 2D to 3D image registration can occur as described in U.S. Patent Application 10/644,680 filed August 20, 2003, incorporated herein by reference.

[0051] The acquired image data can be stored or transferred to the processor system 44 which is a part of the navigation system 20 for use in illustrating a tracked location of the surgical instrument 26 relative to the patient 36. To assist in illustrating the correct location of the surgical instrument 26 relative to the patient 36, the patient space generally defined by the tracking system 22, 24, can be registered to the image data 80 or image space in block 136. The registration of the image data 80 to the patient space can be with any appropriate method, as discussed above.

[0052] The registration of the image data 80 to the patient space can be performed with the EM tracking system 24. The EM tracking system 24, including the localizer 76, can generate a field and navigation space which can be substantially known and definable Euclidean coordinates. The known navigation space can be efficiently and directly registered to Euclidean coordinates of the image data 80. The known field of the EM localizer 76 allows a detected change in the field generated with the EM localizer 76 to be directly related to a distinct position or movement in the field at substantially all points in the field. In other words, a detected changed of movement of the EM tracking device 70b generally equals a selected known movement of the EM tracking device 70b within the field regardless of the position of the EM tracking device 70b within the field generated by the EM localizer 76. Also, every space in the EM navigation domain is known due to the uniform electromagnetic field. Accordingly, a coordinate system identified or defined by the EM tracking system 24 can be substantially known and efficiently applied to the coordinate system of the image data 80.

[0053] The registration of the image data 80 to the patient space identified with the EM tracking system 24 can be performed in any appropriate manner. As discussed above, point, contour, or any other appropriate registration processes can be used. For example, the EM tracking device 70b can be positioned relative to known fiducials or landmarks within the patient 36 and similar or correlated landmarks or fiducials can be identified in the image data 80. The processor system 44, or any appropriate processor system, can then be used to register or correlate the points in the image data 80 to the points of the patient space. Once the registration has occurred, the image data 80 is registered to the patient space identified or within the navigation space defined by the EM tracking system 24.

[0054] The EM tracking system 24 can be registered to the EP tracking system 22 in block 138. The registration or coordination between the EM tracking system 24 and the EP tracking system 22 can occur at any appropriate time, such as before or after the EM tracking system 24 is registered to the image data in block 136. The EP tracking system 22 can be registered to the EM tracking system 24 in block 138 in any appropriate manner. As discussed further herein, exemplary registration systems 138a, 138b, and 138c are illustrated and described in greater detail in relation to Figs. 7A-7C. Once the EP tracking system 22 is registered with the EM tracking system 24, navigation of the instrument 26 with only the EP tracking device 70a can be done in block 140. The navigation with the EP tracking device 70a can be done and a position of the instrument 26 including the tracking device 70a can be navigated relative to the image data 80 due to the registration of the EP tracking system 22 and the EM tracking system 24 in block 138. Accordingly, navigation using only the EP tracking system 22 can occur in block 140.

[0055] With continuing reference to Figs. 5 and 6 and additional reference to Fig. 7A, registration of the EM

tracking system and the EP tracking system, according to various embodiments, is illustrated in block 138a. As discussed above, the lead assembly 92 can include the EP tracking device 70a that can be defined by the tip electrode 90 of the lead 92. The catheter 100 can include one or more coils 102, 104 of the EM tracking device 70b. As illustrated in Fig. 6, the EM tracking device 70b can be used to register the image data 80 to the patient space of the patient 36.

[0056] Once the registration has occurred in block 136, then the EP tracking system 22 can be registered with the EM tracking system 24 in block 138a, illustrated in Fig. 7A. A lead or instrument including an EP electrode can be provided in block 152. The EP electrode can be a distal tip electrode of the lead or can be provided in any other portion, such as in the sheath 94. For example, as illustrated in Fig. 2A, the alternative EP tracking device 70a' can be provided in the sheath 94. Regardless of the position of the electrode it can be used as the EP tracking device 70a and it can be positioned relative to the EM tracking device 70b that is positioned within the catheter 100. In addition, as illustrated in Fig. 2B, the lead including the EP tracking device 70a can be moved relative to the catheter 100 in block 154.

[0057] When moving the lead relative to the catheter 100, it can be determined when the EP tracking device 70a moves past or is near the coils 102, 104 of the EM tracking device 70b in block 156. Various mechanisms can be used to determine when the EP electrode 70a moves past the EM tracking device 70b. For example, a change in impedance, measured voltage, or other determinations can be used to determine when the EP electrode is next to or immediately past the EM tracking device 70b.

[0058] When the determination is made that the EP tracking device 70a has been positioned relative to the EM tracking device 70b, such as substantially in the same position, a registration of the EM tracking system 24 and the EP tracking system 22 can occur in block 158. The registration can occur by substantially coordinating or registering the EP tracking system 22 and the EM tracking system 24. In other words, because the EP tracking system 22 can be used to determine the position of the EP tracking device 70a and the EM tracking system 24 can be used to determine the position of the EM tracking device 70b these two positions or points in patient space can be identified as the same. Accordingly, the navigation space of the EP tracking system 22 can be overlaid or registered with the navigation space of the EM tracking system 24.

[0059] The coordination or registration between the EP tracking system 22 and the EM tracking system 24 can be performed by acquiring a selected number of points that are identical or at known locations relative to one another, as discussed above, with both of the tracking systems. For example, at least three corresponding points may be acquired though more points may be used to actually model or characterize the non-orthogonal or known navigation space defined by the EP tracking system 22. Less information may be necessary in a local or small region than would be needed for a larger space, such as an entire navigation space. Once points with both of the tracking systems have been acquired a curvature model, such as a spline model, can be used to model the EP tracking system 22 coordinate system or navigation space. Other appropriate modeling calculations could also be used to computationally coordinate the EP tracking system 22 and the EM tracking system 24.

[0060] Once the EM tracking system 24 and the EP tracking system 22 have been registered, movement of the EP tracking device 70a within the patient space of the patient 36 can be illustrated superimposed on the image data 80. As illustrated in Fig. 6, icons illustrating the first tracking device 70ai and second tracking device 70bi can be illustrated and superimposed on the image data 80. Once registration has occurred, however, the EP tracking device icon 70ai, illustrating the position of the EP tracking device 70a, can be illustrated separate from the EM tracking device icon 70bi, representing the position of the EM tracking device 70b, but correctly related to the image data 80. It will be understood that an icon 92i can represent generally the surgical instrument 26, or any portion thereof, and not only the tracking devices. The position of the surgical instrument, however, can be identified or determined based upon the tracked position of the tracking device 70.

[0061] Registration of the EP tracking system 22 with of the second navigation space, such as that of the EM tracking system 24, can allow for image navigation of the instrument 26 tracked with only the EP tracking system 22. The navigation space of the EP tracking system 22 may not be substantially uniform or strictly aligned with the image data 80. For example, the tissue of the patient 36 may not be substantially uniform impedance. For example, the impedance of muscle tissue may be substantially different from the impedance of blood or other electrolyte. Accordingly, a particular change in voltage may not always be related to a single physical movement amount of the EP tracking device 70a. Movement of the EP tracking device 70a within the patient 36, however, can be measured using the EP tracking system 22 once it is registered with a tracking system, such as the EM tracking system 24, which can be registered to the image data 80. A registered position of the EP tracking device 70a can be superimposed on the image data 80. Therefore, a position of the EP tracking device 70a can be superimposed on the image data 80 even if a nonuniform navigation space is generated with the EP tracking system 22.

[0062] Returning reference to Fig. 7B, registering the EP tracking system 22 and the EM tracking system 24 can be achieved with registration method 138b. According to the registration method 138b, a catheter can be provided with an EP electrode as the EP tracking device 70a in block 170. A lead assembly can be provided with

the EM tracking device 70b in block 172. The lead can then be moved relative to the catheter in block 174. A determination can be made when the EM tracking device 70b is aligned with or at a selected and known position relative to the EP tracking device 70a in block 176. A registration of the EM tracking system 24 and the EP tracking system 22 can then occur in block 178. The registration method 138b can be substantially similar to the registration method 138a (illustrated in Fig. 7A) save that the EP electrode is positioned in the catheter 100 and the EM tracking device 70b is positioned on the lead. Therefore, registration can occur in substantially the same way and tracking of the EP tracking device 70a can occur and superimposition of a position of the EP tracking device 70a can be illustrated relative to the image data 80.

[0063] Turning to Fig. 7C, a registration method 138c is illustrated. The registration method 138c can include positioning the EM tracking device 70b at a known location in the patient 36 or other navigable space in block 184. The EM tracking device 70b can be any appropriate device, for example the second tracked instrument 26b illustrated in Fig. 4. The second tracked device 26b can be a second instrument moved relative to the patient 36, a dynamic reference frame fixed relative to the patient 36, or any appropriate device including the EM tracking device 70b. For example, the DRF 26b' can be positioned relative to the patient 36 at a fixed and known location. The known location of the DRF 26b' can be determined in any appropriate manner. For example, a registration probe (not illustrated) can be moved relative to the DRF 26b' to determine the location of the DRF 26b'. In addition, the DRF 26b' can be positioned or include a fiducial that is identified in the image data 80 to allow for identification and registration to the image data 80. Alternatively, if the second instrument 26b is a moveable instrument, it can be moved to a landmark that can also be identified within the image data 80.

[0064] When the second tracked device 26b, 26b' is identified relative to the image data 80 and the EM tracking system 24 is registered to the image data 80, the first tracked instrument 26a including the EP tracking device 70a can be moved relative to the second tracked device 26b, 26b'. For example, the first instrument 26a, illustrated in Fig. 4, can move to the location of the DRF 26b' in block 186. Once the first tracked instrument 26a is at the same position as the DRF 26b', registration of the EM tracking system 24 and the EP tracking system 22 can occur in block 188. As discussed above, the location of the two tracking devices 70a, 70b can be determined to be substantially identical when they are positioned next to each other to allow for registration of the two tracking systems 22,24.

[0065] It will be further understood that when two tracked instruments 26a, 26b are provided, they can be positioned at a known position and orientation relative to one another to allow for registration to occur in block 188. For example, it will be understood, the first tracked instrument 26a can be positioned at a known position and orientation relative to the DRF 26b' and registration can occur. In other words, knowing a position and orientation of the DRF 26b' and position and orientation of the EP tracking device 70a can allow for registration of the two tracking systems 22, 24 even if the two tracking devices 70a, 70b are not in substantially identical locations. As discussed above, imaging systems can be used to determine or identify the known locations of the two tracking devices 70a, 70b.

[0066] Registration of the EP tracking system 22 and the EM tracking system, 24 can also occur by providing the EP tracking device 70a and the EM tracking device 70b substantially at the same position on the tracked instrument 26, as illustrated with the instrument 120 in Fig. 3. When the tracking device 70 has substantially only one location for both the EP tracking system 22 and the EM tracking system 24 a determination of registration is not otherwise required, including positioning the EP tracking device 70a relative to the EM tracking device 70b. Rather, the tracked position of the EM tracking device 70b with the EM tracking system 24 can be used to correlate the position of the EP tracking device 70a inherently since all positions determined with the EM tracking device 70b are inherently registered with the EP tracking device 70a. Therefore, the coordinate system of the EM tracking system 24 can be used to illustrate a position of the EP tracking device 70a on the image data 80 at all times. This can allow or be used to acquire more than one point that is the same position with both of the tracking devices 70a and 70b. This can assist in registration of the EP tracking system 22 and the EM tracking system 24. It will be understood, however, that the two tracking devices 70a and 70b need not be the same device to acquire more than one point that is at the same position with both of the tracking devices 70a and 70b.

[0067] Even when the two tracking devices 70a, 70b are the same device or formed to be at the same or fixed relative positions, a third tracking device can be provided. For example, the tip electrode 92 can also be interconnected with the controller 72. Thus, the position of the tip electrode 92 can be tracked once it has exited the catheter 122.

[0068] In addition, or alternatively, it will be understood that the EP tracking device 70a and the EM tracking device 70b need not be positioned on top of one another, but can be positioned substantially at a known fixed location relative to one another or next to each other with a selected assembly. For example, an electrode of the EP tracking device 70a can be positioned substantially abutting coils of wire defining the EM tracking device 70b. They can also be positioned a distance from one another at a substantially known location, at least when a device is at a known configuration. The known relationship or relative positions of the EP tracking device 70a and the EM tracking device 70b can be used to register the EP tracking system 22 and the EM tracking system 24 even if the EP tracking device 70a and the EM tracking device

70b are not at the same location.

[0069] Turning to Fig. 8, navigating the EP tracking device 70a in block 140 is described in further detail. Movement of the EP tracking device 70a can be determined in block 200. The movements of the EP tracking device 70a can then be registered to the coordinates of the EM tracking system 24 in block 202. As discussed above, registration of the EP tracking system 22 and the EM tracking system 24 allow for a registration of a coordinate in the EM tracking system 24 with a determined position of the EP tracking device 70a in the EP tracking system 22.

[0070] Because of the registration of the EP tracking system 22 and the EM tracking system 24, a position of the EP tracking device 70a can be illustrated or displayed on the display device 38, 40 in block 204. As discussed above regarding Fig. 6, a tracked position of just the EP tracking device 70a with the EP tracking system 22 can be displayed on the display device 40 relative to the image data 80. For example, the icon 70ai representing a position of the instrument tracked with the EP tracking device 70a can be displayed on the image data 80.

[0071] Merging preoperative acquired image data, such as the image data 80, can be done to intraoperative acquired image data in block 206. The merging of the image data can occur in any appropriate manner. One appropriate method can include contour merging, which matches contours in the preoperative acquired image data and intraoperative acquired image data. For example, if image data of a vertebra is acquired preoperatively and contours of a vertebra is acquired intraoperatively they can be matched. The contours can be manually or automatically determined in the image data and matched between image data sets.

[0072] Additionally, tracking the EP tracking device 70a can be used to create point clouds for various organs. For example, a point cloud or point cloud map can be generated for a portion of the heart 84. The point cloud can then be matched, such as with contour matching or landmark matching, with preoperative acquired image data. Point cloud matching or generation includes identifying one or more points with the tracking device 70, such as with the EP tracking device 70a to generate a surface of a volume. Appropriate cloud mapping techniques include those described in U.S. Patent Application No. 12/117,537, filed on May 8, 2008, incorporated herein by reference. It will be understood, however, that the generation of the point cloud can be made with either the EP tracking device 70a or the EM tracking device 70b. However, the EP tracking device 70a, which can include an electrode, can be provided at a selected size, such as one that will easily maneuver within the heart 84 to allow for an efficient generation of the cloud map by identifying a plurality of points. Accordingly, a selected one of the tracking devices 70a, 70b can be efficiently used to generate a selected type of data, such as a landmark or cloud map, for merging of intraoperative and preoperative image data.

[0073] In addition, the electrode 92 of the lead 90 can be used as the EP tracking device 70a. The tip electrode 92 can be implanted in the heart 84. Accordingly, image data 80, which can be pre- or intra-operatively acquired, can be used to identify or suggest a selected location of the lead tip 92. By correlating the EM tracking system 24 and the EP tacking system 22 a selected location identified relative to the image data 80 can be used to guide the electrode 92 to an appropriate or selected location for implantation. An additional tracking device, such as the EM tracking device 70b, is not required to track the electrode 92 to a selected location within the heart 84 with the image data 80 because of the registration of the EM tracking system 24 and the EP tracking system 22. Suggesting a placement of a lead tip can be based on any appropriate information, such as historical data, statistical data, or atlas models. Exemplary suggestion systems include those disclosed in U.S. Patent Application Publication No. 2002/0097806, published on May 20, 2004, incorporated herein by reference.

[0074] Providing registered tracking systems can be used for various purposes. As discussed above, the EM tracking system 24 and the EP tracking system 22 can be used for different tracking purposes or in different locations. In addition, the EP tracking system 22 may not generate an appropriate signal in various portions of the patient 36. For example, if the EP tracking device 70a is not positioned within a portion of the patient 36 that includes an electrolyte or appropriately conducted material, a voltage may not be generated relative to the EP tracking device 70a when a current is induced in the patient 36. Therefore, the EM tracking device 70b can be used to track the position of the instrument 26 relative to the patient 36.

[0075] According to various embodiments, the EP tracking device 70a can be substantially smaller than the EM tracking device 70b. For example, the EP tracking device 70a may only include a single wire or small conductive member to act as an electrode. The small dimensions of the electrode of the EP tracking device 70a and can allow it to move to selected locations, such as within the heart 84, which may not be accessible with a larger tracking device, such as the EM tracking device 70b. Therefore, providing the EP Tracking system 22 and the EM tracking system 24 can allow for tracking the surgical device 26, or any appropriate device, with more than one modality.

[0076] The EP tracking system 22 can be used to track the lead electrode 90 as the EP tracking device 70a. Accordingly, the EP tracking system 22 can be used to track the location of the lead electrode 90 to its intended implantation site or location with the EP tracking device 70a. The tracked position can then be displayed on the display devices 38, 40 for viewing by the surgeon 34.

[0077] The EP tracking system 22, however, may not be directly registerable to the image data 80. As discussed above, varying impedances of tissue of the patient 36 may inhibit registration of the EP tracking system

22 with the image data 80. Lack of registration with the image data 80 can reduce effectiveness of image navigation.

[0078] The EM tracking system 24, however, can be registered with the image data 80. The EM tracking system 24, including the more uniform navigation domain, can be registered to the image data 80. In determining one or more points, also referred to as identity points, in both the EP tracking system 22 navigation domain and the EM tracking system 24 navigation domain the two tracking systems can be registered. This can allow the EP tracking system 22 to be registered to the image data 80. Registration can also allow the use of preacquired image data that can be registered to intraoperative image data or other appropriate image data for navigation of the instrument 26 with the EP tracking device 70a.

[0079] In addition, the two tracking systems 22, 24 can be used for complimentary purposes. For example, the EM tracking system 24 may have a higher accuracy than the EP tracking system 22. Therefore the EM tracking system 24 can be used to determine locations of various landmarks for registration, while the EP tracking system 22 is used for navigation of the instrument 26 for implantation. Also, if location and size permits, the EM tracking system 24 can be used to confirm a location of the instrument 26 after implantation.

[0080] Further, the EM tracking system 24 can track the tracking device 70b in the absence of a conductive material. Thus, the EP tracking device 70a can be used to track the instrument when a conductive medium and current is present (e.g. within the heart 84) and the EM tracking device 70b can be used to track the instrument 26 when the conductive medium is not present (e.g. exterior to the heart 84).

[0081] It will be further understood that the tracking systems 22, 24 can be used to track any appropriate device relative to any appropriate volume. For example, positioning a device within an enclosed volume may be selected for building, manufacturing, or repairing various workpieces in selected workspaces. For example, a device can be moved relative to an enclosed volume, such as within an airplane, robot, or other enclosed areas without requiring open visualization or access within the volume. The enclosed volume of the workpiece or workspace, may also include more than one type of environment. Accordingly, having multiple tracking systems using differing tracking modalities can be used to track a single instrument or two parts of the single instrument within any appropriate volume.

[0082] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention.

Claims

1. A system (20) for tracking an instrument within a volume, comprising:

a first electromagnetic tracking system (24) including a first tracking device (70b), wherein the first electromagnetic tracking system is operable to determine a position of the first tracking device within a first tracking domain, wherein the first tracking device includes one or more coils of wire;

a second electropotential tracking system (22) including:

a plurality of current electrodes (60a, 60b, 62a, 62b, 64a, 64b) operable to induce a current into the volume to form a second tracking domain;

a second tracking device (70a) operable to sense a voltage at the second tracking device based upon the induced current;

wherein the second electropotential tracking system is operable to determine a position of the second tracking device within the second tracking domain;

an instrument having a first portion connected to the first tracking device and a second portion connected to the second tracking device to allow tracking of the instrument with at least one of the first tracking system or the second tracking system, wherein the second portion is operable to move relative to the first portion to place the second tracking device at a known position relative to the first tracking device;

a controller (72) in communication with the first electromagnetic tracking system and the second electropotential tracking system;

wherein the controller is operable to determine a registration of the first tracking domain and the second tracking domain to allow the first tracking domain to be overlaid on the second tracking domain based upon the known relative position of the first tracking device and the second tracking device;

wherein the registration is operable to allow image navigation of the instrument with only the second electropotential tracking system in the volume.

2. The system of Claim 1, further comprising:

an imaging system (30) operable to acquire image data of the volume;

wherein the first electromagnetic tracking system is operable to generate an electromagnetic field defining the first tracking domain of a determined uniformity within the volume to allow the first tracking domain to be registered to the image data;

wherein the first electromagnetic tracking system (24) includes a localizer (76);
wherein either of the localizer (76) or the first tracking device (70b) is operable to generate the electromagnetic field and the other of the localizer or the first tracking device is operable to sense the electromagnetic field;
wherein the electromagnetic field defines the first tracking domain.

3. The system of any of the preceding claims, wherein the instrument includes:

an outer member and an inner member, wherein the outer member and the inner member are operable to move relative to one another;
wherein the outer member includes the first tracking device and the inner member includes the second tracking device.

4. The system of any of the preceding claims, wherein the first tracking device is fixedly associated with the volume;
wherein the second tracking device is moveable to a known position relative to the first tracking device;
wherein when the second tracking device is at the known position, the controller is operable to correlate the position of the first tracking device relative to the second tracking device and correlate the first tracking domain relative to the second tracking domain to perform the registration.

5. The system of Claims 1 or 2, wherein the first tracking device and the second tracking device are formed as a single tracking device operable to be tracked within both of the first electromagnetic tracking system and the second electropotential tracking system.

6. The system of Claims 1-4, wherein the instrument includes a lead having the electrode;
wherein the electrode of the lead is for an appropriate device operable to be placed within the volume.

7. The system of Claim 5, wherein the single tracking device includes:

an annular ring operable as an electrode; and
a coil of conductive material wrapped around the annular ring; and
a communication system interconnecting the annular ring and the coil of conductive material with both the first electromagnetic tracking system and the second electropotential tracking system.

8. The system of Claim 7, further comprising:

a display device;
wherein at least one of the first electromagnetic tracking system and the second electropotential tracking system is in communication with the display device and operable to display a represented position of the annular ring, the coil of conductive material, or combinations thereof;
wherein image data is operable to be displayed on the display device relative to the representation of the annular ring and the coil of conductive material.

9. The system of Claim 7, wherein the instrument includes a catheter and a lead moveable within the catheter;
wherein the catheter includes the annular ring and the coil of conductive material around the annular ring;
wherein the catheter defines a cannula and the annular ring and coil of conductive material are positioned around the cannula.

10. A method of tracking an instrument using at least a first tracking system and a second tracking system, comprising:

providing the instrument having a first portion connected to the first tracking device and a second portion connected to the second tracking device to allow tracking of the instrument, wherein the second portion is operable to move relative to the first portion to place the second tracking device at a known position relative to the first tracking device;
providing the first tracking system to determine a position of a first tracking device, including:

generating an electromagnetic field to define a first navigation space in a volume;
determining a first position of the first tracking device with the generated electromagnetic field;

providing the second tracking system to determine a position of a second tracking device, including:

generating a current in the volume to define a second navigation space;
sensing a voltage with the second tracking device induced by the generated current;
determining a second position of the second tracking device based upon the sensed voltage;

moving the second tracking device to a known position relative to the first tracking device;
registering the first tracking system and the second tracking system based upon the known rel-

ative position of the first tracking device and the second tracking device; and
tracking the second tracking device with the second tracking system and illustrating on a display a position of the second tracking device based upon the registration of the first tracking system and the second tracking system.

11. The method of Claim 10, further comprising:

acquiring image data of the volume;
registering the acquired image data to the first navigation space; and
illustrating on the display device the determined first position of the first tracking device.

12. The method of Claims 10 or 11, wherein registering the first tracking system and the second tracking system, includes:

determining a first identity position in the volume with the first tracking device in the first navigation space;
determining a second identity position in the volume with the second tracking device in the second navigation space;
relating a selected plurality of points in the second navigation space with a selected plurality of points in the first navigation space based upon the known first identity position and the second identity position;
calculating a position with the second tracking system of the second tracking device once the second tracking device is no longer at the identity position; and
displaying the tracked position of the second tracking device on the display device relative to the image data.

13. The method of Claim 12, wherein determining the first identity position includes determining a plurality of first identity positions and determining a second identity position includes determining a plurality of second identity positions; and
registering the first tracking system and the second tracking system based on determined plurality of first identity positions and plurality of second identity position.

14. The method of Claim 12, wherein determining a first identity position include positioning the first tracking device at substantially the same location as the second tracking device.

15. The method of Claim 12, wherein determining a first identity position and a second identity position includes determining a first position of the first tracking device and a second position of the second tracking device relative to one another.

Patentansprüche

1. System (20) zum Verfolgen eines Instruments innerhalb eines Volumens, umfassend:

ein erstes elektromagnetisches Verfolgungssystem (24), das eine erste Verfolgungsvorrichtung (70b) umfasst, wobei das erste elektromagnetische Verfolgungssystem betriebsfähig ist, um eine Position der ersten Verfolgungsvorrichtung innerhalb einer ersten Verfolgungsdomäne zu bestimmen, wobei die erste Verfolgungsvorrichtung eine oder mehrere Drahtspulen umfasst;
ein zweites Elektropotential-Verfolgungssystem (22), umfassend:

eine Vielzahl von Stromelektroden (60a, 60b, 62a, 62b, 64a, 64b), die betriebsfähig sind, um einen Strom in das Volumen zu induzieren, um eine zweite Verfolgungsdomäne zu bilden;
eine zweite Verfolgungsvorrichtung (70a), die betriebsfähig ist, um eine Spannung an der zweiten Verfolgungsvorrichtung abzutasten, die auf dem induzierten Strom basiert;
wobei das zweite Elektropotential-Verfolgungssystem betriebsfähig ist, um eine Position der zweiten Verfolgungsvorrichtung innerhalb der zweiten Verfolgungsdomäne zu bestimmen;

ein Instrument, das einen ersten Teil aufweist, der an die erste Verfolgungsvorrichtung angeschlossen ist, und einen zweiten Teil aufweist, der an die zweite Verfolgungsvorrichtung angeschlossen ist, um die Verfolgung des Instruments mit mindestens einem von dem ersten Verfolgungssystem oder dem zweiten Verfolgungssystem zu ermöglichen, wobei der zweite Teil betriebsfähig ist, um sich relativ zu dem ersten Teil zu bewegen, um die zweite Verfolgungsvorrichtung in einer bekannten Position relativ zu der ersten Verfolgungsvorrichtung anzuordnen;
einen Controller (72) in Kommunikation mit dem ersten elektromagnetischen Verfolgungssystem und dem zweiten Elektropotential-Verfolgungssystem;
wobei der Controller betriebsfähig ist, um eine Deckung der ersten Verfolgungsdomäne und der zweiten Verfolgungsdomäne zu bestimmen, damit die erste Verfolgungsdomäne der zweiten Verfolgungsdomäne überlagert werden kann,

basierend auf der bekannten relativen Position der ersten Verfolgungsvorrichtung und der zweiten Verfolgungsvorrichtung;
wobei die Deckung betriebsfähig ist, um eine Bildnavigation des Instruments nur mit dem zweiten Elektropotential-Verfolgungssystem in dem Volumen zu ermöglichen.

2. System nach Anspruch 1, ferner umfassend:

ein Bildgebungssystem (30), das betriebsfähig ist, um Bilddaten des Volumens zu erfassen;
wobei das erste elektromagnetische Verfolgungssystem betriebsfähig ist, um ein elektromagnetisches Feld zu generieren, das die erste Verfolgungsdomäne mit einer bestimmten Einheitlichkeit innerhalb des Volumens definiert, damit die erste Verfolgungsdomäne mit den Bilddaten in Deckung gebracht werden kann;
wobei das erste elektromagnetische Verfolgungssystem (24) ein Visier (76) umfasst;
wobei entweder das Visier (76) oder die erste Verfolgungsvorrichtung (70b) betriebsfähig ist, um das elektromagnetische Feld zu generieren, und das oder die andere des Visiers oder der ersten Verfolgungsvorrichtung betriebsfähig ist, um das elektromagnetische Feld abzutasten;
wobei das elektromagnetische Feld die erste Verfolgungsdomäne definiert.

3. System nach einem der vorhergehenden Ansprüche, wobei das Instrument Folgendes umfasst:

ein äußeres Element und ein inneres Element, wobei das äußere Element und das innere Element betriebsfähig sind, um sich relativ zueinander zu bewegen;
wobei das äußere Element die erste Verfolgungsvorrichtung umfasst und das innere Element die zweite Verfolgungsvorrichtung umfasst.

4. System nach einem der vorhergehenden Ansprüche, wobei die erste Verfolgungsvorrichtung mit dem Volumen fest verknüpft ist;
wobei die zweite Verfolgungsvorrichtung in eine bekannte Position relativ zu der ersten Verfolgungsvorrichtung bewegbar ist;
wobei, wenn sich die zweite Verfolgungsvorrichtung in der bekannten Position befindet, der Controller betriebsfähig ist, um die Position der ersten Verfolgungsvorrichtung relativ zu der zweiten Verfolgungsvorrichtung zu korrelieren, und um die erste Verfolgungsdomäne relativ zu der zweiten Verfolgungsdomäne zu korrelieren, um das in Deckung bringen auszuführen.

5. System nach Anspruch 1 oder 2, wobei die erste Verfolgungsvorrichtung und die zweite Verfolgungsvorrichtung als eine einzige Verfolgungsvorrichtung gebildet sind, die betriebsfähig ist, um sowohl innerhalb des ersten elektromagnetischen Verfolgungssystems als auch des zweiten Elektropotential-Verfolgungssystems verfolgt zu werden.

6. System nach Anspruch 1 bis 4, wobei das Instrument eine Leitung umfasst, die eine Elektrode aufweist;
wobei die Elektrode der Leitung für eine geeignete Vorrichtung gedacht ist, die betriebsfähig ist, um innerhalb des Volumens angeordnet zu werden.

7. System nach Anspruch 5, wobei die einzige Verfolgungsvorrichtung Folgendes umfasst:

einen ringförmigen Kranz, der als Elektrode betriebsfähig ist; und
eine Spule aus leitfähigem Material, das um den ringförmigen Kranz gewickelt ist; und
ein Kommunikationssystem, das den ringförmigen Kranz und die Spule aus leitfähigem Material sowohl mit dem ersten elektromagnetischen Verfolgungssystem als auch mit dem zweiten Elektropotential-Verfolgungssystem zusammenschaltet.

8. System nach Anspruch 7, ferner umfassend:

eine Anzeigevorrichtung;
wobei mindestens eines von dem ersten elektromagnetischen Verfolgungssystem und dem zweiten Elektropotential-Verfolgungssystem in Verbindung mit der Anzeigevorrichtung steht und betriebsfähig ist, um eine dargestellte Position des ringförmigen Kranzes, der Spule aus leitfähigem Material oder von Kombinationen derselben anzuzeigen;
wobei die Bilddaten betriebsfähig sind, um auf der Anzeigevorrichtung relativ zu der Darstellung des ringförmigen Kranzes und der Spule aus leitfähigem Material angezeigt zu werden.

9. System nach Anspruch 7, wobei das Instrument einen Katheter und eine Leitung, die innerhalb des Katheters bewegbar ist, umfasst;
wobei der Katheter den ringförmigen Kranz und die Spule aus leitfähigem Material um den ringförmigen Kranz herum umfasst;
wobei der Katheter eine Kanüle definiert, und der ringförmige Kranz und die Spule aus leitfähigem Material um die Kanüle herum positioniert sind.

10. Verfahren zum Verfolgen eines Instruments unter Verwendung mindestens eines ersten Verfolgungssystems und eines zweiten Verfolgungssystems, umfassend folgende Schritte:

Bereitstellen des Instruments, das einen ersten Teil aufweist, der an die erste Verfolgungsvorrichtung angeschlossen ist, und einen zweiten Teil aufweist, der an die zweite Verfolgungsvorrichtung angeschlossen ist, um die Verfolgung des Instruments zu ermöglichen, wobei der zweite Teil betriebsfähig ist, um sich relativ zu dem ersten Teil zu bewegen, um die zweite Verfolgungsvorrichtung in einer bekannten Position relativ zu der ersten Verfolgungsvorrichtung anzuordnen;
Bereitstellen des ersten Verfolgungssystems, um eine Position einer ersten Verfolgungsvorrichtung zu bestimmen, umfassend folgende Schritte:

Generieren eines elektromagnetischen Feldes, um einen ersten Navigationsraum in einem Volumen zu definieren;
Bestimmen einer ersten Position der ersten Verfolgungsvorrichtung mit dem generierten elektromagnetischen Feld;

Bereitstellen des zweiten Verfolgungssystems, um eine Position einer zweiten Verfolgungsvorrichtung zu bestimmen, umfassend folgende Schritte:

Generieren eines Stroms in dem Volumen, um einen zweiten Navigationsraum zu definieren;
Abtasten einer Spannung mit der zweiten Verfolgungsvorrichtung, die durch den generierten Strom induziert wird;
Bestimmen einer zweiten Position der zweiten Verfolgungsvorrichtung basierend auf der abgetasteten Spannung;

Bewegen der zweiten Verfolgungsvorrichtung in eine bekannte Position relativ zu der ersten Verfolgungsvorrichtung;
in Deckung bringen des ersten Verfolgungssystems und des zweiten Verfolgungssystems basierend auf der bekannten relativen Position der ersten Verfolgungsvorrichtung und der zweiten Verfolgungsvorrichtung; und
Verfolgen der zweiten Verfolgungsvorrichtung mit dem zweiten Verfolgungssystem und Abbilden auf einem Display einer Position der zweiten Verfolgungsvorrichtung basierend auf der Deckung des ersten Verfolgungssystems und des zweiten Verfolgungssystems.

11. Verfahren nach Anspruch 10, ferner umfassend folgende Schritte:

Erfassen von Bilddaten des Volumens;
in Deckung bringen der erfassten Bilddaten mit dem ersten Navigationsraum; und
Abbilden auf der Anzeigevorrichtung der bestimmten ersten Position der ersten Verfolgungsvorrichtung.

12. Verfahren nach Anspruch 10 oder 11, wobei das in Deckung bringen des ersten Verfolgungssystems und des zweiten Verfolgungssystems folgende Schritte umfasst:

Bestimmen einer ersten Identitätsposition in dem Volumen mit der ersten Verfolgungsvorrichtung in dem ersten Navigationsraum;
Bestimmen einer zweiten Identitätsposition in dem Volumen mit der zweiten Verfolgungsvorrichtung in dem zweiten Navigationsraum;
Verknüpfen einer ausgewählten Vielzahl von Punkten in dem zweiten Navigationsraum mit einer ausgewählten Vielzahl von Punkten in dem ersten Navigationsraum, basierend auf der bekannten ersten Identitätsposition und der zweiten Identitätsposition;
Berechnen einer Position mit dem zweiten Verfolgungssystem der zweiten Verfolgungsvorrichtung, sobald sich die zweite Verfolgungsvorrichtung nicht mehr an der Identitätsposition befindet;
und
Anzeigen der verfolgten Position der zweiten Verfolgungsvorrichtung auf der Anzeigevorrichtung bezüglich der Bilddaten.

13. Verfahren nach Anspruch 12, wobei das Bestimmen der ersten Identitätsposition das Bestimmen einer Vielzahl erster Identitätspositionen umfasst und das Bestimmen einer zweiten Identitätsposition das Bestimmen einer Vielzahl zweiter Identitätspositionen umfasst; und
in Deckung bringen des ersten Verfolgungssystems und des zweiten Verfolgungssystems basierend auf der bestimmten Vielzahl erster Identitätspositionen und der Vielzahl zweiter Identitätspositionen.

14. Verfahren nach Anspruch 12, wobei das Bestimmen einer ersten Identitätsposition das Positionieren der ersten Verfolgungsvorrichtung im Wesentlichen an der gleichen Stelle wie die zweite Verfolgungsvorrichtung umfasst.

15. Verfahren nach Anspruch 12, wobei das Bestimmen einer ersten Identitätsposition und einer zweiten Identitätsposition das Bestimmen einer ersten Position der ersten Verfolgungsvorrichtung und einer zweiten Position der zweiten Verfolgungsvorrichtung relativ zueinander umfasst.

Revendications

1. Système (20) pour le suivi d'un instrument dans un volume, comprenant :

   un premier système de suivi électromagnétique (24) incluant un premier dispositif de suivi (70b), dans lequel le premier système de suivi électromagnétique peut fonctionner pour déterminer une position du premier dispositif de suivi dans un premier domaine de suivi, dans lequel le premier dispositif de suivi comprend une ou plusieurs bobines de fil ;
   un second système de suivi à potentiel électrique (22) comprenant :

      une pluralité d'électrodes de courant (60a, 60b, 62a, 62b, 64a, 64b) qui peut fonctionner pour induire un courant dans le volume pour former un second domaine de suivi ;
      un second dispositif de suivi (70a) qui peut fonctionner pour détecter une tension au niveau du second dispositif de suivi sur la base du courant induit ;
      dans lequel le second système de suivi à potentiel électrique peut fonctionner pour déterminer une position du second dispositif de suivi dans le second domaine de suivi ;

   un instrument ayant une première partie connectée au premier dispositif de suivi et une seconde partie connectée au second dispositif de suivi pour permettre le suivi de l'instrument avec au moins un élément entre le premier système de suivi ou le second système de suivi, dans lequel la seconde partie peut fonctionner pour se déplacer par rapport à la première partie afin de placer le second dispositif de suivi à une position connue par rapport au premier dispositif de suivi ;
   un contrôleur (72) en communication avec le premier système de suivi électromagnétique et le second système de suivi à potentiel électrique ;
   dans lequel le contrôleur peut fonctionner pour déterminer un enregistrement du premier domaine de suivi et du second domaine de suivi pour permettre au premier domaine de suivi d'être superposé au second domaine de suivi sur la base de la position relative connue du premier dispositif de suivi et du second dispositif de suivi :

      dans lequel l'enregistrement peut fonctionner pour permettre une navigation de l'image de l'instrument avec seulement le second système de suivi à potentiel électrique dans le volume.

2. Système de la revendication 1, comprenant en outre :

   un système d'imagerie (30) qui peut fonctionner pour acquérir des données relatives à l'image du volume ;
   dans lequel le premier système de suivi électromagnétique peut fonctionner pour générer un champ électromagnétique définissant le premier domaine de suivi d'une uniformité déterminée dans le volume pour permettre au premier domaine de suivi d'être enregistré dans les données relatives à l'image ;
   dans lequel le premier système de suivi électromagnétique (24) inclut un localisateur (76) ;
   dans lequel un premier élément entre le localisateur (76) ou le premier dispositif de suivi (70b) peut fonctionner pour générer le champ électromagnétique, et le second peut fonctionner pour détecter le champ électromagnétique ;
   dans lequel le champ électromagnétique définit le premier domaine de suivi.

3. Système de l'une quelconque des revendications précédentes, dans lequel l'instrument comprend :

   un membre externe et un membre interne, dans lequel le membre externe et le membre interne peuvent se déplacer l'un par rapport à l'autre ;
   dans lequel le membre externe comprend le premier dispositif de suivi et le membre interne comprend le second dispositif de suivi.

4. Système selon l'une quelconque des revendications précédentes, dans lequel le premier dispositif de suivi est associé de manière fixe au volume ;
   dans lequel le second dispositif de suivi peut être déplacé à une position connue par rapport au premier dispositif de suivi ;
   dans lequel lorsque le second dispositif de suivi est à une position connue, le contrôleur peut fonctionner de façon à corréler la position du premier dispositif de suivi par rapport au second dispositif de suivi et corréler le premier domaine de suivi par rapport au second domaine de suivi pour réaliser l'enregistrement.

5. Système des revendications 1 ou 2, dans lequel le premier dispositif de suivi et le second dispositif de suivi forment un dispositif de suivi unique qui peut fonctionner pour être suivi aussi bien dans le premier système de suivi électromagnétique que dans le second système de suivi à potentiel électrique.

6. Système des revendications 1-4, dans lequel l'instrument comprend un fil ayant l'électrode ;
   dans lequel l'électrode du fil correspond à un dispositif approprié qui peut fonctionner pour être placé

dans le volume.

7. Système de la revendication 5, dans lequel le dispositif de suivi unique comprend :

une bague annulaire pouvant fonctionner comme une électrode ; et
une bobine à base de matériau conducteur enroulée autour de la bague annulaire ; et
un système de communication interconnectant la bague annulaire et la bobine à base de matériau conducteur aussi bien avec le premier système de suivi électromagnétique qu'avec le second système de suivi à potentiel électrique.

8. Système de la revendication 7, comprenant en outre :

un dispositif d'affichage ;
dans lequel au moins un élément entre le premier système de suivi électromagnétique et le second système de suivi à potentiel électrique est en communication avec le dispositif d'affichage et peut fonctionner pour afficher une position représentée de la bague annulaire, de la bobine à base de matériau conducteur, ou une combinaison de celles-ci ;
dans lequel la donnée relative à l'image peut fonctionner pour être affichée sur le dispositif d'affichage par rapport à la représentation de la bague annulaire et de la bobine à base de matériau conducteur.

9. Système de la revendication 7, dans lequel l'instrument comprend un cathéter et un fil mobile à l'intérieur du cathéter ;
dans lequel le cathéter comprend la bague annulaire et la bobine à base de matériau conducteur autour de la bague annulaire ;
dans lequel le cathéter définit une canule et la bague annulaire et la bobine à base de matériau conducteur sont positionnées autour de la canule.

10. Procédé de suivi d'un instrument utilisant au moins un premier système de suivi et un second système de suivi, comprenant :

la fourniture de l'instrument ayant une première partie connectée au premier dispositif de suivi et une seconde partie connectée au second dispositif de suivi pour permettre le suivi de l'instrument, dans lequel la seconde partie peut fonctionner pour se déplacer par rapport à la première partie pour placer le second dispositif de suivi à une position connue par rapport au premier dispositif de suivi :

la fourniture du premier système de suivi pour déterminer une position d'un premier dispositif de suivi, incluant :

la génération d'un champ électromagnétique pour définir un premier espace de navigation dans un volume ;
la détermination d'une première position du premier dispositif de suivi avec le champ électromagnétique généré ;

la fourniture du second système de suivi pour déterminer une position d'un second dispositif de suivi, incluant :

la génération d'un courant dans le volume pour définir un second espace de navigation ;
la détection d'une tension avec le second dispositif de suivi induite par le courant généré ;
la détermination d'une seconde position du second dispositif de suivi basée sur la tension détectée ;

le déplacement du second dispositif de suivi à une position connue par rapport au premier dispositif de suivi ;
l'enregistrement du premier système de suivi et du second système de suivi sur la base de la position relative connue du premier dispositif de suivi et du second dispositif de suivi ; et
le suivi du second dispositif de suivi avec le second système de suivi et l'illustration sur un affichage d'une position d'un second dispositif de suivi sur la base de l'enregistrement du premier système de suivi et du second système de suivi.

11. Procédé de la revendication 10, comprenant en outre :

l'acquisition de données relatives à l'image du volume ;
l'enregistrement de données relatives à l'image acquises sur le premier espace de navigation ; et l'illustration sur le dispositif d'affichage de la première position déterminée du premier dispositif de suivi.

12. Procédé des revendications 10 ou 11, dans lequel l'enregistrement du premier système de suivi et du second système de suivi inclut :

la détermination d'une première position d'identité dans le volume avec le premier dispositif de suivi dans le premier espace de navigation ;
la détermination d'une seconde position d'iden-

tité dans le volume avec le second dispositif de suivi dans le second espace de navigation ;
la liaison d'une pluralité de points sélectionnés dans le second espace de navigation avec une pluralité de points sélectionnés dans le premier espace de navigation sur la base de la première position d'identité connue et de la seconde position d'identité connue ;
le calcul d'une position avec le second système de suivi du second dispositif de suivi une fois que le second dispositif de suivi ne se trouve plus à la position d'identité ; et
l'affichage de la position suivie du second dispositif de suivi sur le dispositif d'affichage relatif aux données relatives à l'image.

13. Procédé de la revendication 12, dans lequel la détermination de la première position d'identité inclut la détermination d'une pluralité de premières positions d'identité et la détermination d'une seconde position d'identité inclut la détermination d'une pluralité de secondes positions d'identité ; et
l'enregistrement du premier système de suivi et du second système de suivi sur la base de la pluralité déterminée de premières positions d'identité et la pluralité déterminée de secondes positions d'identité.

14. Procédé de la revendication 12, dans lequel la détermination d'une première position d'identité inclut le positionnement du premier dispositif de suivi essentiellement au même emplacement que le second dispositif de suivi.

15. Procédé de la revendication 12, dans lequel la détermination d'une première position d'identité et d'une seconde position d'identité inclut la détermination d'une première position du premier dispositif de suivi et d'une seconde position du second dispositif de suivi l'un par rapport à l'autre.

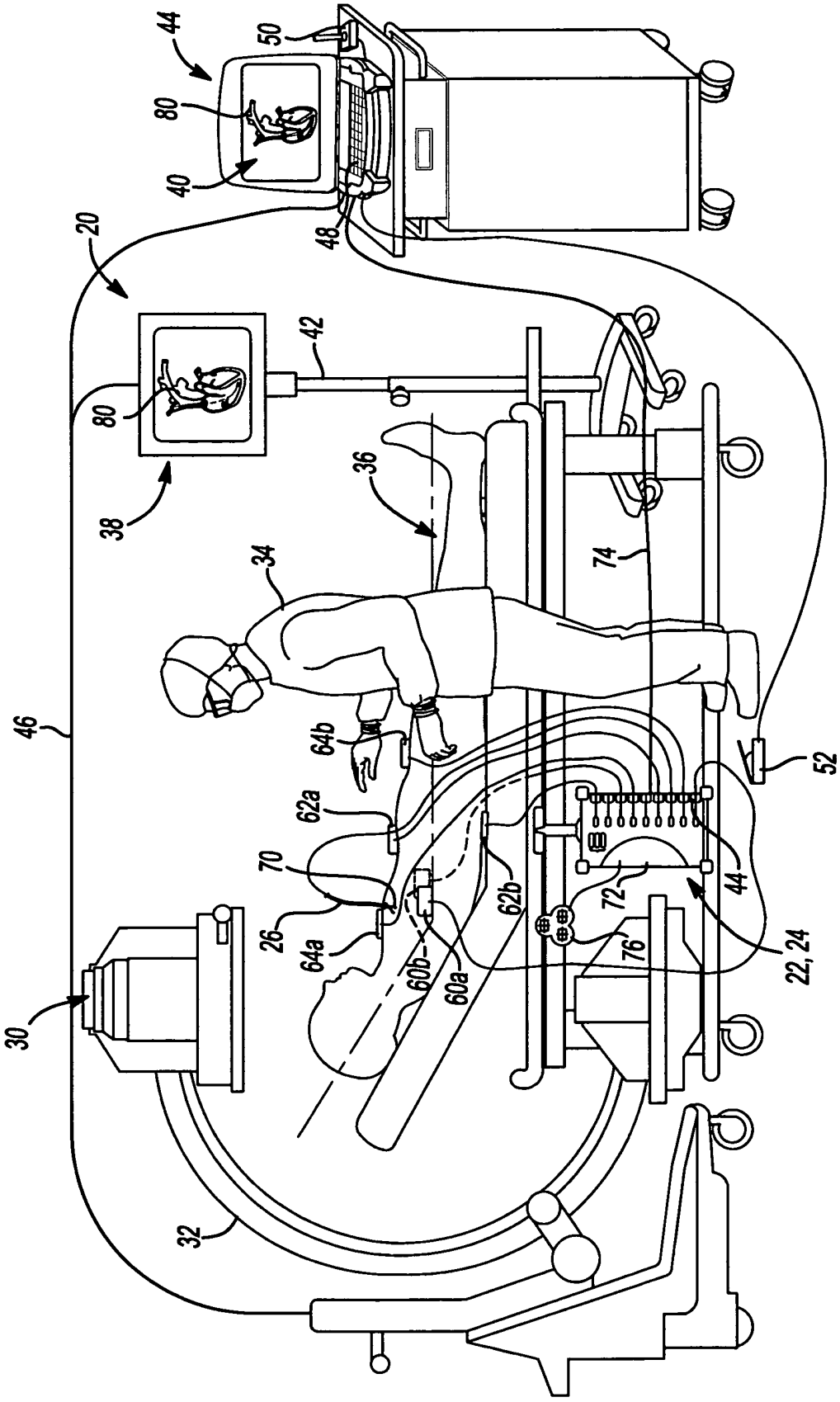
44
50
80
40
48
20
42
80
38
36
34
74
46
64b
62a
52
70
62b
44
26
72
64a
60b
60a
76
22, 24
30
32

Fig-1

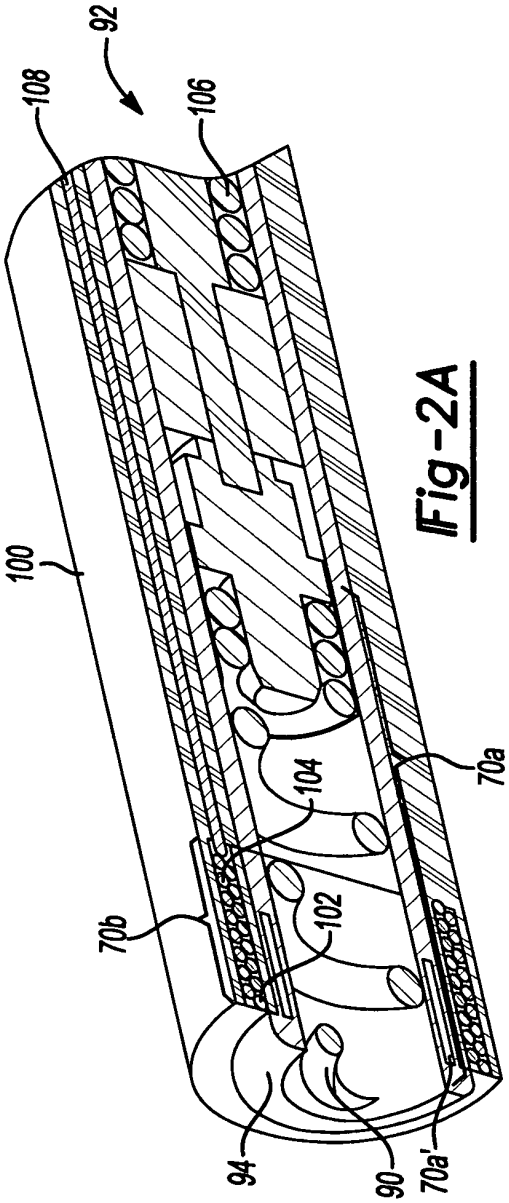
92
108
106
100
104
70a
70b
102
94
90
70a'

Fig-2A

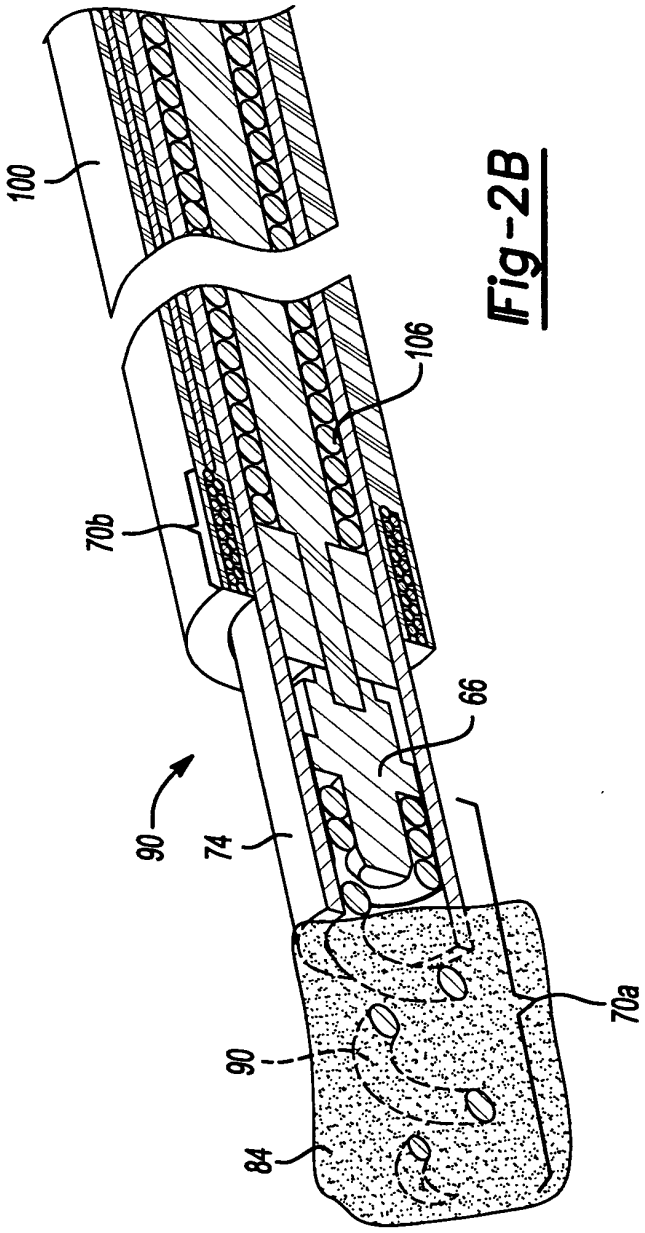
100
106
70b
66
90
74
70a
90
84

Fig-2B

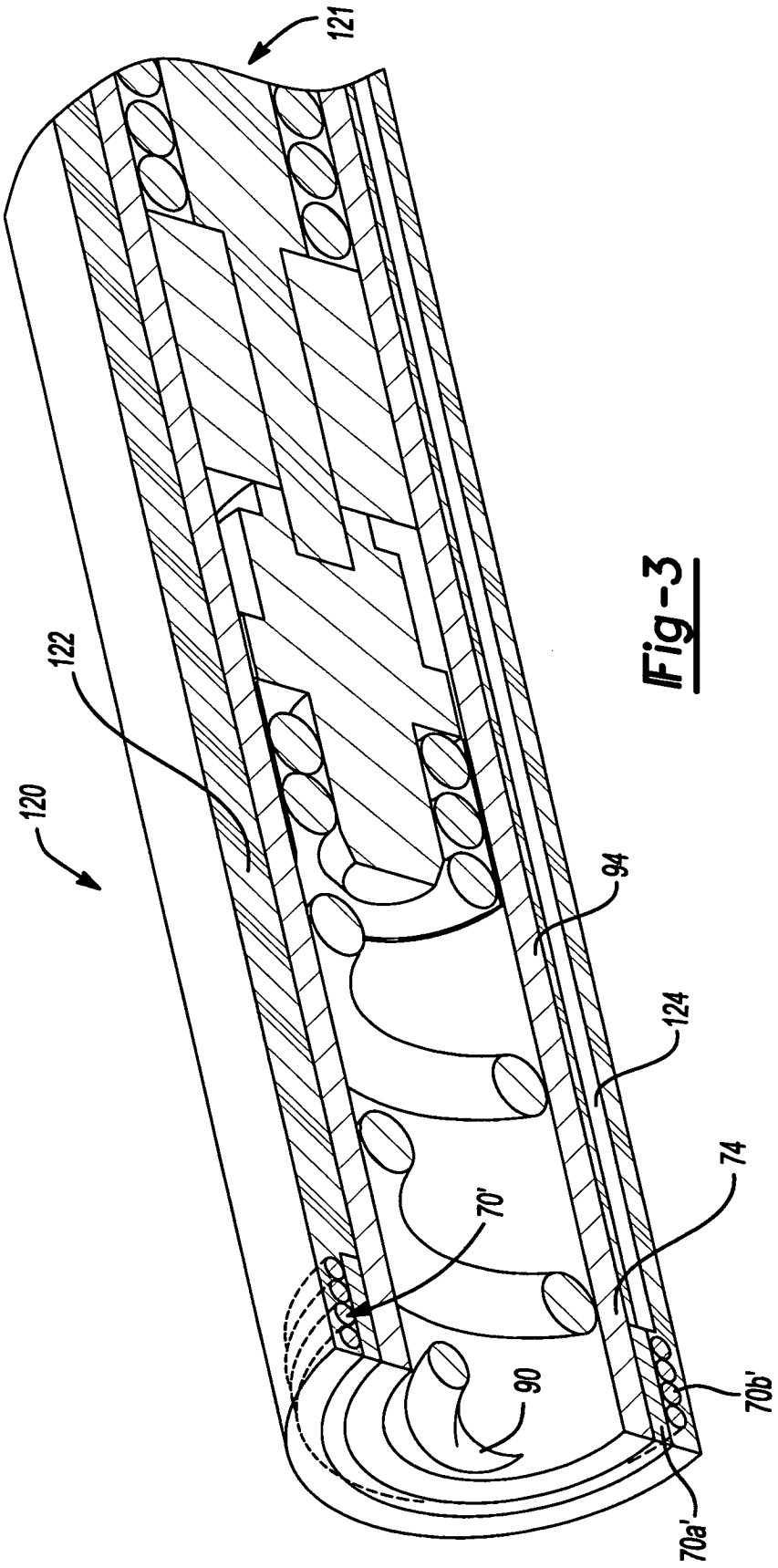

Fig-3

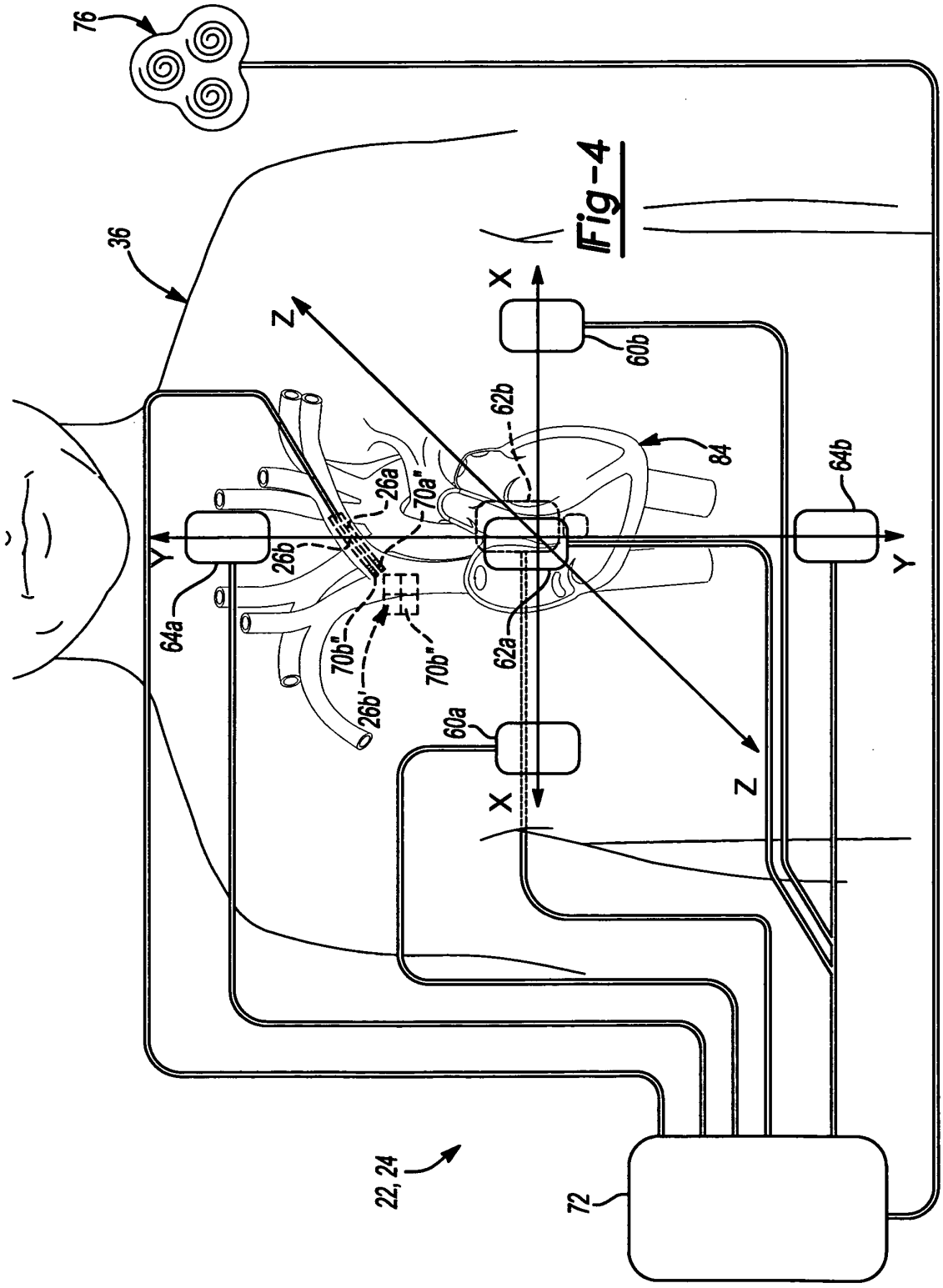
76
36
X
Z
60b
62b
84
64b
Y
26a
70a"
26b
64a
70b"
70b'
26b'
62a
60a
Z
X
Y
22, 24
72

Fig-4

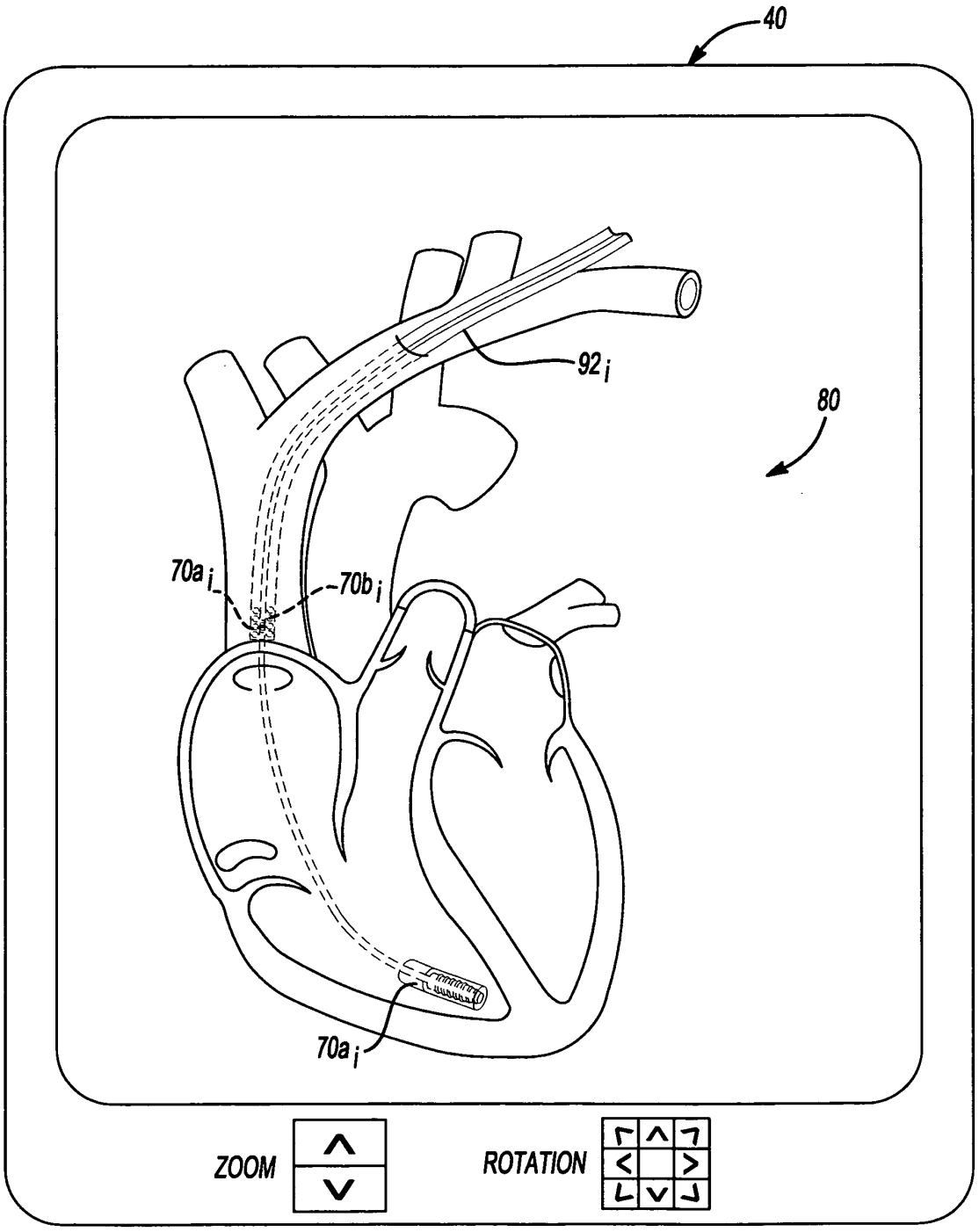

Fig-6

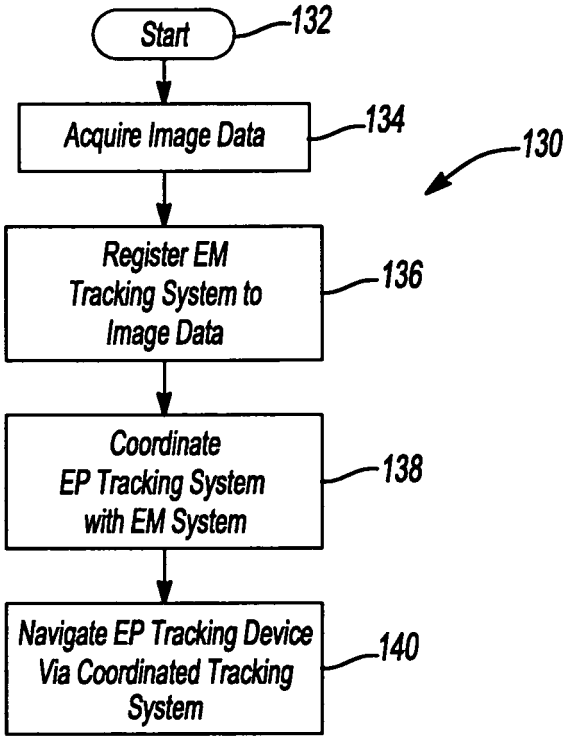
Start
132
Acquire Image Data
134
130
Register EM Tracking System to Image Data
136
Coordinate EP Tracking System with EM System
138
Navigate EP Tracking Device Via Coordinated Tracking System
140

Fig-5

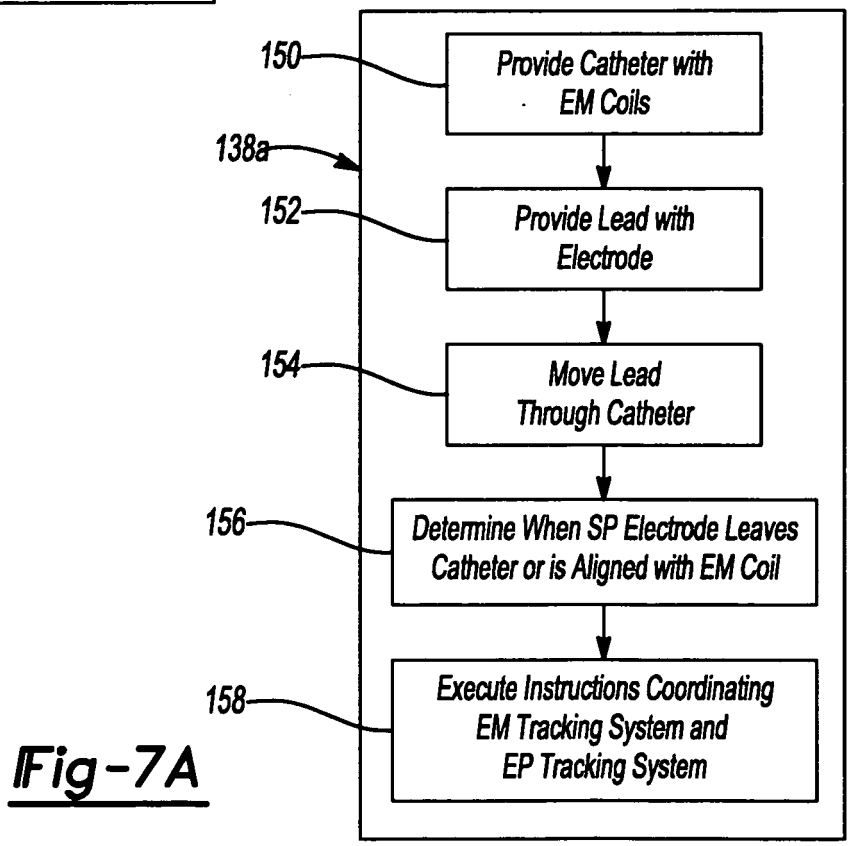
150
Provide Catheter with EM Coils
138a
152
Provide Lead with Electrode
154
Move Lead Through Catheter
156
Determine When SP Electrode Leaves Catheter or is Aligned with EM Coil
158
Execute Instructions Coordinating EM Tracking System and EP Tracking System

Fig-7A

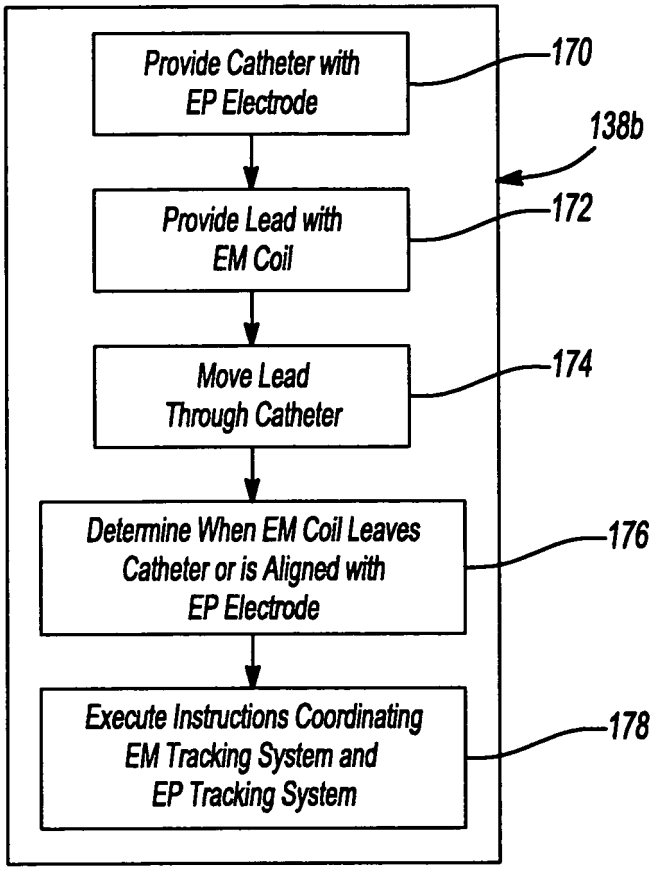
Provide Catheter with EP Electrode
170
138b
Provide Lead with EM Coil
172
Move Lead Through Catheter
174
Determine When EM Coil Leaves Catheter or is Aligned with EP Electrode
176
Execute Instructions Coordinating EM Tracking System and EP Tracking System
178

Fig-7B

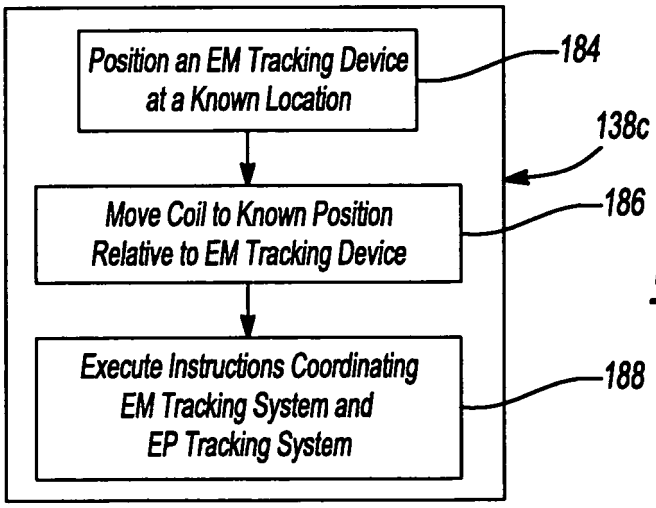
Position an EM Tracking Device at a Known Location
184
138c
Move Coil to Known Position Relative to EM Tracking Device
186
Execute Instructions Coordinating EM Tracking System and EP Tracking System
188

Fig-7C

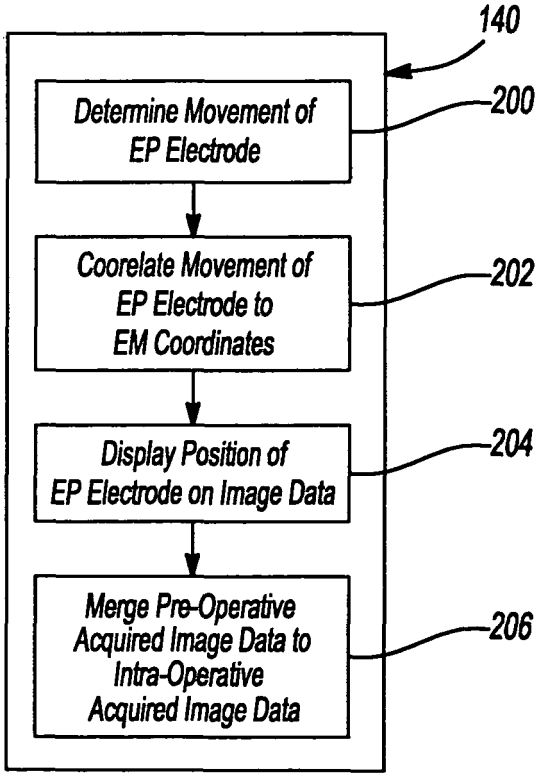
140
Determine Movement of EP Electrode
200
Coorelate Movement of EP Electrode to EM Coordinates
202
Display Position of EP Electrode on Image Data
204
Merge Pre-Operative Acquired Image Data to Intra-Operative Acquired Image Data
206

Fig-8

REFERENCES CITED IN THE DESCRIPTION

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